UNIVERSITY OF CALIFORNIA.

AGRICULTURAL EXPERIMENT STATION.

BULLETIN NO. 71.

The Use of Gases Against Scale Insects.

Some time ago the Agricultural Department was requested by Messrs. A. B. and A. S. Chapman, Mr. L. H. Titus and Mr. J. C. Newton, prominent orange-growers of Los Angeles county, to conduct experiments with the view of determining the efficacy of certain gases as insecticides—with special reference to the white scale, *Icerya Purchasi*. The following is a summary of results, of which a full report will be published hereafter.

The use of gases for this purpose has been long contemplated, and various appliances have been suggested for the ready application of any efficacious gas. The ease with which gas penetrates to all parts of the tree naturally suggests its use as preferable to washes, which at best leave many parts of the foliage and infested branches untouched, even when sprayed with the greatest care. In order that the gas may be an efficient insecticide, it must be so poisonous that even when applied in small quantities it produces fatal results; for in the application the air confined in the tent covering the tree dilutes the gas to a great extent. Again, the gas must be capable of being generated quickly in sufficient volume. The record below shows that only one of the gases employed fulfilled these conditions to a satisfactory extent. Preliminary experiments with some others having shown their unfitness for the purpose, either on account of expense or because of injury to the foliage, or imperfect action on the insec ts, their study was not pursued further.

Appliances for Application.

The tent for covering the tree is made of heavy bed-ticking, thoroughly oiled with linseed oil. This cloth serves the purpose best, as it is very closely woven, is pliable and easily folded.

The support of the tent, devised by Mr. Titus, is a very ingeniously contrived scaffolding mounted on wheels, which serve to move it from one tree to another. Its dimensions are 26 feet high, with a base 20x20 feet. Its upper part is 20x12, and carries upon the top a roller made of galvanized iron (6 inches in diameter and 12 feet long), upon which the tent is rolled when taken from the tree. Side guy-ropes are attached to the bottom of the tent and run through pulleys at the upper corners of the scaffold. They are used to open the tent when it is to be dropped over the tree, and to fold it up when it is removed. The lightness of the apparatus allows of its being easily removed by two men, who operate the whole. If necessary, two or more tents can be handled by the same scaffolding, one tent being left over the tree while the scaffolding is moved to the next.

In adjusting the tent, the bottom is placed on the ground about three feet from the tree and covered with earth. This brings the gas to bear upon the base of the tree and the surrounding soil.

The generator in which the gases were produced consists of a heavy sheet-iron cylinder, 11 inches in diameter and 13 inches high. The bottom rests on a plank, and to the top is fitted a movable cover suspended in a frame by a bench-screw. Into the cover are fitted two pieces of gas-pipe—one for the exit of the gas toward the tent, and the other, connected with a pump, carries the gas which returns *from* the tent. Two small reservoirs are also inserted in the cover; in these are contained the solutions which are to flow into the generator for the production of the gas.

In order to establish circulation and to force the gas into the tent, a pump is used, which also serves to exhaust the gas from the upper part of the tent and to force it again through the generator. It is proposed to replace the pump by a small fan-blower, which is much more expeditious than the common pump which was used.

The Gases Experimented With.

Among the gases used were chlorine, sulphuretted hydrogen, ammonia, carbon bisulphide, carbon monoxide, carbonic acid, hydrocyanic acid, and carbolic acid vaporized by heat.

Chlorine. — Some preliminary experiments were made in small vessels into which this gas had been introduced. Some infested branches were allowed to remain in them for times varying from 5 to 35 minutes, without any noticeable effect being produced on the insect. Atmospheres more strongly saturated with the gas proved fatal to the insect in a short time. In other treatments extending over 18 hours,

with less saturated atmospheres, only a small percentage of the insects was killed. No decided effects were noticeable on the foliage unless the gas was very concentrated.

Carbon Bisulphide.—A lime tree, 12 feet in diameter of top, was treated with the vapor of 2½ pounds of sulphide of carbon for 45 minutes. At the end of this time the insects were lively, and during the treatment had crawled up and collected around a rope surrounding the tree, at the point where the gas was being injected from the hose. It proved that the gas thus used injures neither the insects nor the foliage. It is upon record, however, that in cases where the vapor has not been thoroughly diffused, but was allowed to flow down from an open vessel placed in the top of the tent, serious injury was done to the foliage at points where the undiluted vapor flowed down.

Sulphuretted Hydrogen.—Several treatments with this gas were made on a small scale, the application lasting from 5 to 35 minutes. The effects produced either with diluted or concentrated gas were similar to those produced by chlorine, except that even the concentrated sulphuretted hydrogen did not injuriously affect the foliage. An experiment in which a whole tree was treated in the tent for 45 minutes, with quite concentrated sulphuretted hydrogen gas, showed clearly that the effect was far from being satisfactory; the insects for the moment were stupefied, but in the course of an hour and a half the majority of them were again moving about.

Ammonia.—The vapor from one pound and a half of strong ammonia water was applied to an 11-foot lime tree for 30 minutes. The results were disastrous to the foliage; the leaves were all scalded, and in a few days all dropped from the tree, and even the newer growth of wood was injured. The insects, however, were not perceptibly harmed.

Carbon Monoxide.—Very strong hopes have been entertained by many for the successful application of this gas. Its apparent cheapness and easy production, when the necessary plant is once erected, would recommend it. Unfortunately our experiments show that it is not sufficiently effective to warrant its use. The gas was obtained by forcing air through a small furnace filled with red-hot charcoal, care being taken to cool and to measure the gas before applying it. No appreciable effect was noticeable after 40 minutes. In a duplicate experiment, in which the charcoal was more strongly ignited and continuously introduced into the barrel for 30 minutes, only slightly better results were obtained.

Oxalic Acid.—It was thought that the production of carbon monoxide by decomposition of oxalic acid by heat might be substituted for the previous method of generating this gas. One-quarter of a pound of oxalic acid was ignited, and the gases applied in a manner similar to that of the preceding experiment. Neither the insects nor the foliage were harmed in the least. This experiment has incidentally shown that the vapor of formic and oxalic acids, also produced during the heating of the latter is likewise ineffective.

Carbolic Acid.—It had been suggested that carbolic acid vaporized by heat would prove fatal to the insect. A dose of half a pound of liquid acid was volatilized in the furnace, and the vapor blown in the vessel containing the infected branch. At the end of 20 minutes all the old insects were still alive, and some of the young ones, just molted, were moving about. An hour later the foliage appeared as if scalded.

Hydrocyanic Acid.—It was only with hydrocyanic, or prussic acid (generated by the action of sulphuric acid on potassium cyanide), that sufficiently fatal effects were secured to warrant a more thorough determination of the time of exposure and quantities of material which would produce the best results. Numerous experiments were carried on for this purpose, and it was shown that even small amounts were effective. It was also shown that even in these small quantities an injurious effect upon the foliage was produced. In the beginning of the experiments, "mining cyanide" of potassium was used. It is a very impure material and contains along with the cyanide a considerable amount of carbonate of potassium. For this reason many of the first treatments were practically ineffective.

Later treatments with pure cyanide were more successful in destroying the insects, but the foliage was proportionally injured. Treatments varying in dose from 4 to 12 ounces of cyanide, and in time from 15 to 60 minutes, showed that the effect produced on the foliage by longer treatment was not proportionally greater than that produced by short treatment. Neither was the effect of longer treatments proportionally more fatal to the insects. It was thus clearly shown that the gas mixture should be of considerable strength in order to insure rapid action.

The effect of the gas was so disastrous to the foliage that it became necessary to find some means of remedying this trouble. This was sought in applying a second gas, which might preserve the foliage. Sulphuretted hydrogen was therefore injected into the tent, together with the cyanide gas, both from the same generator; a portion of the sulphuretted hydrogen being introduced before the cyanide was generated. It was found that the insects appeared stupefied when the tent was raised, but large numbers revived in a few hours. The effect of the cyanide seemed therefore to have been decreased by the sulphuretted hydrogen. The foliage was not preserved, although not so badly affected as by treatments with cyanide alone.

Carbonic acid gas was next tried. Trees were treated with larger doses of cyanide than heretofore used, and the carbonic acid from 1½ pounds of carbonate of soda was at the same time introduced with these doses. The insects were killed and the foliage of a 12-ft. tree remained unharmed, while that of a 14-ft. tree with the the same amount of carbonic acid was slightly injured. Thus it was shown that it would require 1½ pounds of bicarbonate of soda to preserve tree-tops 12 feet in diameter, and that with this protection the deadly cyanide could be successfully used.

The regulation of the doses for the different sized trees so as to produce uniform treatments

is calculated on the basis of the results of the experiments which determined the amount of each constituent for a 12-foot tree. The following table indicates the amounts for trees of different dimensions of top, based upon the rates of cubical contents:

Size of Tree, feet.	Cyanide of Potassium, fluid ozs.	Bi-Carbonate of Soda, pounds.	Sulphuric Acid, fluid ozs.
4	.7	.05	.4
5	1.6	.11	.3
6	2.5	.20	1.3
7	4.0	.29	2.1
8	6.0	.44	3.1
9	8.5	.63	4.5
10	11.5	.87	6.2
11	15.5	1.14	8.2
12	20.0	1.50	11.6
13	25.4	1.90	13.5
14	31.6	2.50	16.6
15	39.2	2 92	20.7
16	47.5	3.55	25.2
17	57.5	4.23	30.1
18	67.7	5.05	35.8
19	70.9	5.93	42.1
20	90.5	6.93	49.2

In order to apply the doses easily they are prepared so that the required amounts of each ingredient can be directly measured. The cyanide solution is prepared by dissolving say 10 pounds of the solid salt in about 2¼ gallons of water, warmed nearly to the boiling point, stirring at intervals, cooling, and then diluting to 2½ gallons. This solution will contain about one ounce of cyanide of potassium to 2½ fluid ounces of the liquid.

The bicarbonate of soda is pulverized finely and measured off in a vessel marked, so as to designate pounds and fractions of a pound of the solid material. It is then placed in the generator and the dose of cyanide mixed with it, and, if necessary, a little water added to make it into a thin paste. After adding the measured dose of sulphuric acid, the pump is worked slowly at first, and more rapidly after the gas has passed into the tent. The time for each treatment must be determined by future experiments; 15 minutes seemed to be quite sufficient when the cyanide alone was used, but it may be desirable to extend the treatment to 30 minutes when the foliage is protected by the carbonic acid gas.

It is advisable that the treatments should follow cultivation after about four days, so that all weeds and places where the insect may find lodgment would be destroyed. The insect will then be on, or very near, the tree; the fitting of the tent to the ground is thus also much easier.

The eggs of the insect remained apparently uninjured, wherever protected by the woolly covering. A second treatment, to destroy such as may afterward hatch, will therefore be necessary.

It must not be understood that these experiments definitely settle the mode of operation and the size of the doses to be used. They are merely suggestive of a general plan which can be so perfected in the future that the application of this remedy to other kinds of trees and insects must be attended with good results. It simply remains for the ingenious cultivator to devise the necessary appliances for its use, on a small scale, on all sorts of fruit trees, shrubs and plants.

It must not be forgotten that extreme care in the handling both of this deadly gas and of the cyanide itself is necessary. To inhale the one, or to taste or touch a wound with the other, may lead to serious consequences.

Berkeley, June 12. F. W. MORSE.

Action of the Los Angeles Supervisors.

Just after the foregoing was written, the following letter was received from A. Scott Chapman, of San Gabriel, member of the California State Board of Horticulture:

SAN GACRIEL, June 8, 1887.

F. W. Morse, University of California—DEAR SIR: The Board of Horticulture of Los Angeles county have been out to examine the work done by you at Mr. Titus' place and have pronounced it the best "killing" that they have ever seen.

They asked my father (Mr. A. B. Chapman) to go before the Board of Supervisors and make a statement of your work. He went before the board and explained things to them. They then agreed to pay all the expenses incurred by him and Mr. Titus; they further agreed to ask you to come down again and carry your plan to completion, agreeing to pay all your expenses and salary, the same as was done by Mr. Titus and my father, during your previous visit.

Very respectfully yours,

A. SCOTT CHAPMAN.